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Why Farmers Sometimes Love Risks: Evidence from India

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I. Introduction

In developing countries, where the majority of the population depends on agriculture, incomes often display a considerable amount of variation due to fluctuations in rainfall, disease, and pest pressure. As few insurance possibilities exist, attitudes toward risk are crucial determinants of economic decisions and in particular investment behavior.[1]

The extensive literature that tries to measure risk attitudes has sometimes inferred them from economic decisions (see, e.g., Moscardi and De Janvry 1977; Antle 1987). Other studies have attempted to directly elicit preferences

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[1] While several studies have confirmed the existence of informal insurance networks in village economies (see, e.g., Townsend [1994] for a study in the context of this article), full insurance has not been confirmed as of yet for households facing large nonidiosyncratic risk (where risk correlates within the insurance network). See also Mahul and Wright (2003) for a discussion on the welfare implications of crop insurance.

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over risky distributions (see, e.g., Dillon and Scandizzo 1978; Binswanger 1980; Just and Lybbert 2009; Yesuf and Bluffstone 2009; Liu 2013).[2] Following in the line of this second strand of the literature, we conducted experiments to measure the attitudes toward risk among cotton farmers in three villages in India. These attitudes were elicited via farmers' evaluations of hypothetical (but realistic) production alternatives involving various risky outcomes. Each alternative was presented as a probability distribution over cotton yield outcomes. The farmers then indicated their willingness to pay for a bag of cotton seeds that would result in such a distribution.

The results point to the surprising prevalence of risk seeking in the households in our sample. As many as 85% of the sampled farmers expressed a willingness to pay more for riskier distributions. The willingness to accept risk in return for the potential to achieve high payoffs bears a strong negative relation to household wealth. Qualitative as well as statistical evidence suggests that these apparently anomalous results might be rationalized by credit constraints in combination with nonconvexities in production associated with large fixed-cost investments.[3] Irrigation and higher education in children appear to be two prominent examples of such investments.

Our findings on risk attitudes are markedly different from the existing literature, which has by and large found moderate to large degrees of risk aversion. For example, Binswanger (1980) measures attitudes toward risk among the same households studied in this article using two methods: an experimental approach with real and hypothetical payoffs of various magnitudes and an interview method. The results of the experimental method indicate that at medium-sized payoff levels (equivalent to the monthly salary of an unskilled laborer), virtually all individuals are moderately risk averse, with little variation according to personal characteristics. More recently, Liu (2013), using a low-stakes (equivalent to the daily wage of a laborer), real payoff experimental method, finds evidence of both risk and loss aversion among Chinese cotton farmers, in addition to overweighting of low probabilities. Akay et al. (2011), using low-stakes experiments among Ethiopian farmers, find that almost 80% of the sample is risk averse. Yesuf and Bluffstone (2009) conduct medium-stakes experiments in Ethiopia, with real payoffs set in an agricultural context. They

[2] The literature on risk in agriculture and risk in the context of developing countries is vast, and any attempt to summarize it would necessarily be incomplete. For an overview, see (among others) Moschini and Hennessy (2001).

[3] It is well known that farmers face credit constraints in developing countries. See Rosenzweig and Wolpin (1993) and Fafchamps and Pender (1997) for studies set among the same households studied in this article.

find that depending on the expected payoff and range, one-third to two-thirds of households are severely risk averse. De Brauw and Eozenou (2011) ask farmers in Mozambique to choose between two hypothetical varieties of sweet potato, a less risky and a more risky variety, and find that the average farmer in their sample is risk averse.

We believe the distinctiveness of our results is due to the high stakes involved: for the average farmer in our sample, achieving the best outcome in the hypothetical distribution would generate over Rs 16,000 in revenue on a per acre basis, a very sizable amount that is comparable to the farmer's annual income. At such levels, it appears likely that the tendency to avert risk is overridden by the possibility of moving to a new, permanently higher level of income by undertaking a large investment that would normally be unaffordable. We also think that our results, while different, are not necessarily incompatible with the findings of prior studies. The logic that high-fixed-cost investments with high returns can justify risk loving in the face of high-payoff gambles would also imply that if the payoffs are not large enough then these investments may be out of the question, in which case we would find ourselves back in the world of risk aversion.

We are aware of three other studies that have found evidence of risk-loving behavior among farmers. Ross, Santos, and Capon (2012) use small-stakes, real payoff experiments in Lao People's Democratic Republic and find that the majority of the respondents act in a risk-loving manner, and about half of the respondents are ambiguity averse. Just and Lybbert (2009) conduct medium-stakes experiments in Tamil Nadu (India) with real payoffs set in an agricultural context similar to ours and find that only 49% of farmers are risk averse in a comparison of two lotteries, one of which is a mean-preserving spread of the other. Dillon and Scandizzo (1978) report that a small but significant fraction of farmers in their study (set in Brazil) could be classified as risk loving on the basis of their measure. Although the difference in context, time period, and methodology makes comparisons with our study difficult, these findings suggest that we may need to move away from our traditional view of the risk-averse farmer.

The idea that nonconvexities can induce risk taking, while intuitive, has so far largely remained a theoretical possibility (see, e.g., Lybbert and Barrett 2011; Lybbert et al., forthcoming). We believe ours to be the first empirical exploration of this idea. More generally, this article answers the call of Just and Pope (2003), who argue that many alternative explanations can be offered for observed behavior under risk, only one of which is curvature of the utility function. The observed risk response might also be due to technology, physical constraints, or financial asymmetries. In order to properly infer or measure risk aversion from observed choices, one needs to carefully isolate the impacts of all these factors.

The article proceeds as follows. Section II describes the study site and the experiment, Section III analyzes the results of the risk experiment, Section IV presents an illustrative model, and Section V concludes.

II. Description of the Study Site and Experiment

A. Study Site

Table 1 introduces the three villages selected for this study. These villages have been followed for over 35 years by the Village Level Studies (VLS) program of the International Crop Research Institute of the Semi-Arid Tropics (ICRISAT).[4]

Aurepalle, with 925 households, is the largest of the three villages. It is located in the drought-prone, poor Telangana region of Andhra Pradesh and, in terms of average income, is situated between the richer Kanzara and the poorer Kinkhed. Kanzara and Kinkhed, with 319 and 189 households, respectively, are located in the less drought-prone Akola district of West Maharashtra. The VLS sample includes 128, 63, and 55 households in Aurepalle, Kanzara, and Kinkhed, respectively. In both Akola villages, households own, on average, 5–6 acres of land. In Aurepalle, this is significantly less, at about 3.4 acres. The average size of a household is four to five members in all three villages.

The average education level of the respondent (i.e., the main decision maker with regard to agriculture) is low, especially in Aurepalle (2.3 years). It is important to note that in these villages, enrollment in school is very high (93% of the children between 6 and 15 years old are in school), but the rate drops sharply at the higher-education level (21% of the young adults between 19 and 21 years old are enrolled in an education institute). This might be partially due to credit constraints. Higher education can be expensive in India, ranging from Rs 1,000 to Rs 100,000 for a degree, yet very few of the farmers in Aurepalle and Kinkhed report having access to bank credit. In Kanzara 18% have access to bank credit.[5]

In all three villages, agriculture is one of the main sources of income, and cotton is the main cash crop. Over 80% of the households in Kanzara and

[4] For an overview of the goals, method, and outcomes of the VLS, see Singh, Binswanger, and Jodha (1985), Walker and Ryan (1990), Bantilan et al. (2006), and Rao and Charyulu (2007).

[5] While credit is available from other sources, such as input dealers, moneylenders, and informal networks (see Besley [1995] for an introduction), the respondents reported that in terms of large amounts of credit for productive purposes only the banks (and in some cases the company selling the equipment) are an option.

TABLE 1

BASIC DESCRIPTIVE STATISTICS OF AUREPALLE, KANZARA, AND KINKHED

	Aurepalle	Kanzara	Kinkhed
Number of households in village	925	319	189
Number of households in sample	128	63	55
Number of households in the experiment	95	57	54
Median rainfall, 2001–7 (mm/year)	434	748	745
Distance to nearest town (km)	10	9	12
Average land owned (acre)*	3.4	5.2	6
Average dryland owned (acre)*	2.4	2.1	2.6
Average irrigated land owned (acre)*	1	3	3
Average number of household members	4.23	4.87	4.50
Average annual income (Rs)†	43,543	53,720	38,087
Average education level of respondent (in years)	2.31	6.61	6.89
Average maximum level of education in household (years)	7.08	10.41	10
% of children enrolled in school, 2001–8	91	100	95
% of young adults enrolled in an educational institute, 2001–8	32	32	27
% of households that farm cotton, 2001–8	60	84	82
Average cotton yield, 2007–8 (Q/acre)	8.97	3.50	1.88
Average cotton yield, 2001–4 (Q/acre)‡	3.53	5.76	4.90
Average cotton yield, 2005–7 (Q/acre)‡	4.46	2.47	3.21
Income from agriculture (% of kharif income)§	55	70	66
Average seed price non-Bt cotton (Rs/acre)‖	650	411	625
Average seed price Bt cotton (Rs/acre)‖	1,280	929	1,196
% of respondents who have access to irrigation	42	30	27
% of respondents with access to bank credit#	1.12	17.54	0

Note. Average/percentage/median statistics refer to the sample in each village in 2007–8 unless otherwise noted. Children are defined as being between age 6 and 15, and young adults are defined as being between age 15 and 25. Q = quintal; Bt = *Bacillus thuringiensis*.

* Includes the landless households.

† 2004–5 household-level income as reported in the ICRISAT-VLS.

‡ Calculated using the ICRISAT-VLS input-output data.

§ Based on the income earned from all agriculture-related activities at the time of interview during the kharif season (rainy season, the main agricultural season); this might be an underestimate as not all of the harvest was sold at that point in time.

‖ The average of what respondents—on average—expect a bag sufficient for 1 acre of seed to cost (note that the expected seed cost varies a lot by cultivar).

Respondent was asked who he would approach for credit to buy agricultural inputs and how likely he would be to receive credit from this individual/organization. Multiple answers were possible. Percentage here corresponds to the respondents who said that they have access to government or private bank credit.

Kinkhed farm cotton. In Aurepalle, due to the relatively large number of landless families, this number is lower at 60%.[6] The average cotton yield varies strongly from year to year. In 2007–8, it was around 9 Q/acre in Aurepalle, 3.5 Q/acre in Kanzara, and 2 Q/acre in Kinkhed.[7]

Losses in cotton production in this region are due (among other things) to its predominant cultivation under rain-fed conditions: both droughts and, more recently, floods are an issue. The average cotton yield in Kanzara and

[6] Based on ICRISAT data for the last 7 years.

[7] 1 quintal (Q) = 100 kilograms.

Kinkhed during the last few years was lower in comparison to 2001–4, a result the farmers attribute to excess rainfall and flooding. In 2007–8, 42%, 30%, and 27% of the respondents in Aurepalle, Kanzara, and Kinkhed, respectively, reported having access to irrigation at some point during the year. Irrigation not only reduces rainfall-related risks during the rainy season but also allows for cultivation during the dry season.[8] Both surface water (rivers, canals, ponds, and basins) and groundwater (wells) are used as irrigation sources. The water is applied on the field through flood irrigation, drip irrigation, or sprinkler irrigation. We have no information on the installation of drainage systems but have data on whether the farmer perceives waterlogging to be a (general) problem on his plots: less than 1% of the plots are considered to have problems.

The cost of a well, irrigation, or drainage system is substantial, amounting to several times the average annual income. The cost of a well varies, depending on the depth of the water table. When the water table is more than 8 meters below the ground, a submersible pump must be used to lift the water, whereas a centrifugal pump is sufficient if the water table is less than 8 meters below ground level (Gibson and Singer 1969). The cost of a deep well is more than four times the cost of a shallow well (Sekhri 2011). In addition, there is an element of risk, owing to the fact that the depth of the groundwater table in a particular area is usually not known in advance.

B. *Description of the Experiment*

The farmers' risk attitudes were assessed by presenting them with a set of hypothetical yield distributions. Differently from prior experimental studies of risk preferences, we explicitly framed our lotteries in terms of yield from an agricultural crop (cotton). This served to add realism to the experiment, which partly compensated for the hypothetical nature of the payoffs. Providing a familiar context made it easy for the farmers to understand the gambles and what they represented.

The experiments were conducted among all ICRISAT-VLS respondents who had farmed in the past 7 years or who were thinking of farming in the future (206 of the 246 ICRISAT-VLS respondents). Henceforth, we refer to this set of respondents as the "farmers." Details on the experimental setup are included in appendix A.

[8] Considering the benefits of irrigation in the rainy season, the average profit for an irrigated cotton plot is Rs 6,030/acre (SD: Rs 8,298/acre) versus Rs 4,051/acre (SD: Rs 5,348/acre) for an unirrigated plot.

The risk experiment, based on Lybbert and Just (2007) and Just and Lybbert (2009), consisted of four hypothetical farming seasons. For each "season" the farmer was asked through a verbal exercise his willingness to pay (WTP) for a bag of cotton seed with a particular yield distribution (sufficient to sow 1 acre of cotton). To deal with illiteracy and innumeracy, we used a visual method based on Lybbert and Just (2007): Fisher-Price building blocks were vertically stacked, to present the various cotton yield distributions (in quintals [Q] per acre). We used a total of 20 blocks, each block representing 5%, and three different colors. Green represents the high yield (i.e., 8 Q/acre). Yellow represents the average yield (i.e., 6 Q/acre), and red represents the low yield (i.e., 4 Q/acre). The average output price is about Rs 2,100/Q, so these numbers correspond to Rs 8,400, Rs 12,600, and Rs 16,800 in revenues. We opted for yield distribution, as opposed to revenue or profit distribution, as this setup aligned closely with how the farmers themselves thought about risk.

We aimed to design the experiment such that the average yields one could obtain were comparable to what farmers are actually obtaining in the field. However, as the average yield on the field varied a lot from year to year, this was not an easy task. We tried out various specifications during the trial round, first basing our yields on the average obtained in 2001–7 (which is about 4 Q/acre, so the yields offered were 2 Q/acre, 4 Q/acre, and 6 Q/acre), but according to the farmers' own account this was much too low for them to even consider buying these seeds. They explained to us that with the new genetically modified seeds on the market, the average yields were on the increase. Hence, we decided to redesign the experiment and base our yields on their current reference point; that is, the average yield in 2007–8 was 5.5 Q/acres. Comparing these outcomes with the average yield levels in three villages, one can see that for the Aurepalle farmers, this distribution is at the lower end of what they are currently achieving, while for the Akola farmers it is at the higher end, especially for Kinkhed (mainly due to the excess rainfall in the last few years in Akola).

We started with two trial distributions to help the farmers learn the game and then did four experiments, in the order reflected in table 2. We did not randomize the order of the distributions, and we recognize that order effects might be a concern. Holt and Laury (2005) find systematic scaling up of risk aversion by ordering larger payoffs after lower payoffs lotteries, and they ascribe this to learning effects (see also Harrison et al. [2005] for a discussion). However, Alpizar, Carlsson, and Naranjo (2010) find no significant order effects in real risk experiments framed in an agricultural manner among coffee farmers in Costa Rica. We take up this issue in greater detail in Section III.

TABLE 2
HYPOTHETICAL YIELD DISTRIBUTIONS

	Trial Distribution		Actual Distribution			
	T_1	T_2	L_1	L_2	L_3	L_4
4 Q/acre	100	50	25	30	30	10
6 Q/acre	0	50	50	40	30	55
8 Q/acre	0	0	25	30	40	35
Expected value	4	5	6.0	6.0	6.2	6.5
Variance	0	1	2.0	2.4	2.8	1.6

Note. 1 quintal (Q) = 100 kg. Data represent probabilities multiplied by 100.

The two trial distributions and the four actual lotteries are presented in table 2. Of the latter, the first baseline distribution has an expected yield of 6 Q/acre and a variance of 2 Q/acre. The second distribution has the same expected yield but a higher variance than the first distribution, namely, 2.4 Q/acre. Thus, the first distribution second-order stochastically dominates (SOSD) the second distribution. The third distribution has a higher expected yield than the first one but also a considerably higher variance, 6.2 Q/acre and 2.76 Q/acre, respectively. The fourth distribution first-order stochastically dominates (FOSD) the first distribution, with an expected yield of 6.5 Q/acre and a variance of 1.55 Q/acre, and FOSD a distribution that SOSD the third distribution. Note also that both the fourth and the third distribution FOSD the second distribution.

The effect of using hypothetical payments as opposed to real payments has not yet been settled in the literature. The validity depends on the nature of the experiment and elicitation method. In this case, one may argue that "the subjects have no special reason to disguise their true preferences" (Kahneman and Tversky 1979, 265) as their decision has no financial consequences. Binswanger (1980), who conducted monetary experiments among the same households as we did, found that the distribution of risk aversion in hypothetical games was more dispersed than the distribution of risk aversion in real games but that once the real game was played there was no difference between the hypothetical and the real choices. In addition, he found that respondents are significantly more risk averse in a hypothetical high-stakes game (Rs 500) compared to a real medium-stakes game, indicating that hypothetical payoffs do not necessarily induce risk seeking. Kachelmeier and Shehata (1992), who conducted laboratory experiments among Chinese students, detected no response differences between no monetary payments and low monetary payments or between low and high nominal values in the absence of actual monetary payments. In their survey of the literature, Beattie and Loomes (1997) conclude that "the absence (or presence) of financial incentives is not a crucial factor in encouraging (or discouraging) violations of standard axioms in pairwise (risky) choice problems" (165). Holt and Laury (2002), however, who conducted experiments with students at three US universities, find that respondents are more risk loving when confronting hypothetical high-stakes (over US dollar;100) experiments versus real high-stakes experiments. They conclude that "subjects facing hypothetical choices cannot imagine how they would actually behave under high-incentive conditions" (1654).

A key point to be noted is that all of the above-mentioned experiments tried to provide a context-free environment, in order to ensure that the results could not be attributed to framing. In contrast, our experiment was explicitly framed as a seed-buying experience, and as a result we believe that our respondents had less trouble imagining how they would react. In addition, our experience was that the respondents understood the setup well. The setup was first tried out among nonsample respondents and perfected using their feedback.[9] During the actual data collection, respondents were not asked to explain their choices but requested to indicate if they could not understand the question well.[10] Only a few respondents appeared confused, and all replied with reasonable estimates within the range of the actual seed prices (see the discussion of table 3 in Sec. III.A). The fact that this experiment was preceded by one in which we elicited the respondent's beliefs about the yield of various cotton cultivars using the same tools might have also contributed to their understanding.

III. Analyzing Preferences

A. Risk-Loving Behavior

We refer to the lotteries in table 2 as T_1 and T_2 (the two trial distributions) and L_1, L_2, L_3, and L_4 (the actual distributions). Table 3 presents the descriptive statistics on the willingness to pay (WTP) for the actual lotteries.

[9] We conducted both a qualitative round and a pilot (trial) round among 40 nonsample farmers in person before the actual data were collected. The qualitative round provided general information on the perception of risk and uncertainty, while the pilot round provided us with the opportunity to adjust the setup of the experiment. The respondents in the trial round were asked to give feedback on the setup of the experiment and the choices they made. The fact that we were working in the ICRISAT villages helped, as the respondents were used to being interviewed and offered many valuable suggestions.

[10] The enumerators had a checklist to ensure the respondent understood the question (when eliciting the beliefs, e.g., the enumerator held up one block and asked how much that block represented—5 %—etc.). Blank looks, inconsistent answers, and oddly shaped distributions indicated to us that the setup with the blocks was not yet understood, and we had to repeat the explanation.

TABLE 3
WILLINGNESS TO PAY (Rs)

	Mean	SD	Median
Distribution 1 (L_1)	705	380	580
Distribution 2 (L_2)	790	469	600
Distribution 3 (L_3)	926	553	700
Distribution 4 (L_4)	930	516	750

Note. Mean (SD, median) willingness to pay (WTP) for the first trial distribution (not shown here) was 395 (234, 300); mean (SD, median) WTP for the second trial distribution was 551 (304, 450).

The median WTP ranges from Rs 580 for the first lottery to Rs 750 for the fourth lottery.[11] (We should also note that all but one farmer preferred all the actual lotteries to T_1, while 94% of the farmers preferred all the actual lotteries to T_2—this is due to the fact that the trial experiments were unambiguously dominated by the real experiments.)

We begin with a number of checks of internal consistency of preferences that follow from first-order stochastic dominance and transitivity (see also table 4): (1) 85% (strictly) prefer L_4 to L_2, 87% (strictly) prefer L_4 to L_1, and 99% (strictly) prefer L_3 to L_2. (2) Then, anyone who (strictly) prefers L_3 to L_4 must also (strictly) prefer L_3 to L_1: this turns out to be true 94% of the time. (3) Further, anyone who (strictly) prefers L_3 to L_4 and also (strictly) prefers L_1 to L_2 must then also (strictly) prefer L_3 to L_2: this turns out be true 100% of the time. (4) Anyone who (strictly) prefers L_4 to L_3 must also (strictly) prefer L_4 to L_2: this happens 100% of the time. (5) Anyone who (strictly) prefers L_2 to L_1 must also (strictly) prefer L_3 to L_1: this is true 99% of the time. So preferences look, by and large, internally consistent.

We now test the implications of risk aversion. Our first measure of risk lovingness is based on a comparison of the individual's WTP for lotteries L_1 and L_2, with L_2 representing a mean-preserving spread of L_1. This permits a sharp categorization of individuals: a risk-neutral person would be exactly indifferent between the gambles, while a risk-loving person would strictly prefer L_1 to L_2. One could categorize risk neutrality as being either weak risk aversion or weak risk loving. We adopt the former convention, treating risk neutrality as weak risk aversion (i.e., not evidence of risk loving) so as to focus our attention on strict risk seeking. Our second measure of risk lovingness is based on a comparison of the individual's WTP for L_3 and L_4. The second measure of risk lovingness does not allow as sharp a categorization as the first measure because L_3 has lower expected value as well as higher risk than L_4.

[11] Note that these are in the range of the actual seed prices ranging from about Rs 400 to Rs 1,300 in table 1.

TABLE 4
DO FARMERS OBEY FOSD AND SOSD?

Prediction	Should Be True	Validity in the Data*
$L_4 > L_2$	For everyone (by FOSD)	85% (with 10% indifferent)
$L_4 > L_1$	For everyone (by FOSD)	87% (with 9% indifferent)
$L_3 > L_2$	For everyone (by FOSD)	99% (with 1% indifferent)
$L_4 > L_3$	For risk-averse individuals (by SOSD and then FOSD)	52% (with 9% indifferent)
$L_1 > L_2$	For risk-averse individuals (SOSD)	11% (with 5% indifferent)
$L_3 > L_1$	Ambiguous	95% (with 3% indifferent)

Note. FOSD = first-order stochastic dominance; SOSD = second-order stochastic dominance.
* Percentage of individuals for whom the prediction was true. Percentage of the farmers who attached equal value to both prediction lotteries is shown in parentheses.

In this comparison, any risk-neutral person would strictly prefer L_4 over L_3, and the same might be true for some moderately risk-loving individuals. We therefore treat a tie in this case as corresponding to risk lovingness.

Table 4 shows the percentage of sampled individuals whose stated preferences are in line with these predictions. Remarkably, only 11% of the respondents appear to be strictly risk averse when choosing between lotteries L_1 and L_2 (and 5% of the respondents are willing to pay the same amount). In the intermediate comparison involving L_3 and L_4, nearly 48% of respondents violate the predictions of risk aversion (with 9% of the respondents being indifferent between the two lotteries).

The measure of risk lovingness based on the comparison between L_3 and L_4 is particularly useful because one may suspect that there may have been an order effect in terms of comparing L_1 and L_2 that led to respondents believing that the distributions were getting better (following the two trial experiments). However, when comparing L_3 to L_4, the order effect would have to be reversed in order for someone to appear risk loving. In particular, L_4 looks extremely attractive relative to L_3 (at least to a risk-averse individual), yet nearly 48% of the respondents proved to be risk loving in this comparison, preferring L_3 over L_4. Appendix table C1 shows the results from regressing WTP on the order of the lottery, controlling for individual fixed effects. On average, the WTP increases significantly going from L_1 to L_3 but does not change significantly going from L_3 to L_4, reflecting the fact that a number of individuals prefer L_3 to L_4. To the extent that there is an order effect in operation whereby subjects prefer later lotteries to earlier ones, the comparison of L_3 and L_4 may actually be underestimating the extent of risk lovingness.

To gain a better understanding of what drives WTP, we regress WTP on the probabilities of the distributions, education level, wealth, and output prices and input costs. The intuition behind this is as follows: if the farmer obeys expected utility and displays risk aversion, then the magnitude of the effect of increasing the probability of the best outcome (while reducing the probability of the middle outcome) should be smaller compared to the effect of increasing the probability of the worst outcome (while reducing the probability of the middle outcome).

Expressed mathematically, define x_i as the outcome, u_i as the corresponding utility level, and p_i as the probability of achieving outcome i. If $u'(\cdot) > 0$, $u''(\cdot) < 0$, $0 < x_2 - x_1 = x_3 - x_2$,[12] then

$$\frac{\partial \mathrm{WTP}}{\partial p_1} = \frac{u_1 - u_2}{u'_1 p_1 + u'_2 p_2 + u'_3 p_3}, \tag{1}$$

$$\frac{\partial \mathrm{WTP}}{\partial p_3} = \frac{u_3 - u_2}{u'_1 p_1 + u'_2 p_2 + u'_3 p_3}, \tag{2}$$

$$|u_3 - u_2| < |u_1 - u_2| \Rightarrow \left|\frac{\partial \mathrm{WTP}}{\partial p_3}\right| < \left|\frac{\partial \mathrm{WTP}}{\partial p_1}\right|, \tag{3}$$

with WTP defined as

$$u(w + \text{outside}) = \sum p_i u(w - \mathrm{WTP} + x_i), \tag{4}$$

where w = initial wealth and outside = outside option (i.e., sowing noncotton crops).

Table 5 presents the results of this analysis. We approximate the WTP function by a linear model.[13] Model 1 includes the respondent's education level, village-level fixed effects, and wealth. Model 2 additionally includes the 2007–8 cotton yield as a regressor, as this may influence the results by setting a reference point in the farmer's mind. Note that the number of observations used to estimate the model is substantially less than in model 1, as it includes only the respondents who farmed cotton in 2007–8, as opposed to all farmers. Model 3 includes farmer-level fixed effects.[14]

[12] Note that in our case $x_1 = oQ_1 - c$, $x_2 = oQ_2 - c$, and $x_3 = oQ_3 - c$, with $Q_1 = 4$, $Q_2 = 6$, $Q_3 = 8$, o = output price, and c = input cost.

[13] Note also that even when one uses a simple expected utility model to explain the variation in the WTP, the WTP will depend in a nonlinear manner on the characteristics of the distribution of the outside option and the distribution of the gamble presented to the respondent, the output price and input cost, and the respondent's preferences with regard to risk.

[14] Recall that each respondent expresses his WTP for four lotteries.

TABLE 5
CORRELATES OF WILLINGNESS TO PAY

	OLS		Fixed Effects
	Model 1	Model 2	Model 3
Probability of obtaining 4 Q/acre	−367.340***	−319.634***	−319.634***
	(57.326)	(39.572)	(49.711)
Probability of obtaining 8 Q/acre	1,564.197***	1,527.106***	1,527.106***
	(102.163)	(106.803)	(72.890)
Education level of decision maker (years)	4.972	7.473	
	(5.462)	(5.963)	
Wealth (land) per capita (1,000 Rs)	.118	.133	
	(.096)	(.102)	
Wealth (other assets) per capita (1,000 Rs)	−.303	−.231	
	(.451)	(.583)	
Aurepalle fixed effect	−87.026	12.899	
	(62.764)	(109.600)	
Kinkhed fixed effect	694.595***	755.298***	
	(76.097)	(97.329)	
Output produced in 2007–8 (Q/acre)		−6.083	
		(12.546)	
Constant	242.147***	202.641**	445.863***
	(68.535)	(92.025)	(27.482)

Note. Standard errors in parentheses are clustered at the individual level. Dependent variable in the ordinary least squares (OLS) regressions is the willingness to pay for a lottery. Fixed effects refer to the inclusion of individual-level fixed effects. The value of other assets was computed using the 2006–7 ICRISAT data; other assets include livestock, savings, borrowings and lendings, machinery, equipment, other durable goods, and stocks. Q = quintal.
** $p < .05$.
*** $p < .01$.

While the distributions represent yield rather than profits, it is possible that respondents were factoring input and output prices in their calculations. These prices are known only for farmers who farmed cotton in 2007–8. For these farmers, we regress the output price and input costs of 2007–8 on a series of household and individual-level variables. Table C2 reports the results. The average output price is about Rs 2,100/Q, while the average cost of inputs, other than seeds (not including the costs of the quasi-fixed investments such as land and irrigation but including the value of family labor and self-produced inputs), is about Rs 5,800/acre. As table C2 shows, there is some variation in prices between villages but no significant variation within villages. For this reason, we think it is reasonable to omit prices from our set of explanatory variables, as long as we are including village fixed effects.

The results in table 5 indicate that WTP is largely driven by the probability of the best outcome. Increasing the probability of the best outcome by 10% increases WTP by, on average, Rs 153–57, while increasing the probability of the worst outcome by the same magnitude decreases WTP by, on average, Rs 32–37. That is, WTP is more sensitive to the probability of the highest outcome than to the probability of the lowest outcome. As such, it is clear that standard static expected utility will not explain the variation in the data unless farmers are risk loving.

Overall, the three models give very similar results. The yield of the last season (2007–8) does not have a statistically significant effect on WTP in model 2. However, as the regressions include a village-level fixed effect, one cannot conclude from this result that the reference point has no impact on WTP, as the village-level fixed effects might be absorbing the majority of this effect.

The Kinkhed fixed effect is substantial in magnitude. The fixed effects represent between-village-level variation in climatic conditions, characteristics of the agricultural system (such as intercropping), the outside options available to the farmer if the "bet" is rejected, or reference point effects. As the climate and agricultural conditions in Kanzara are similar to the ones in Kinkhed, the positive sign on the Kinkhed dummy variable could imply that the outside options for farmers in Kinkhed are less favorable compared to Kanzara farmers. Education, which could potentially influence WTP by changing the outside option of the farmer, does not appear to have any relation to WTP.

B. The Relationship between Risk-Loving Behavior and Household Assets

The violations of risk aversion in the data are striking in terms of what they indicate about the prevalence of risk-taking behavior. Interviews with the farmers before the data collection (during the pilot round) indicated that they were disproportionately attracted to the possibility of achieving the high payoff associated with 8 Q/acre. Some of the farmers explicitly justified their choices by explaining that if the high outcome were achieved they would be able to invest in large projects such as irrigation for their farm or higher education for their children.

With this in mind, we now examine some of the correlates of risk-taking behavior. We begin with some simple summary statistics. We segregate the respondents into four groups in table 6: group 1 consists of respondents who are risk averse in that they (weakly) prefer L_1 to L_2 and strictly prefer L_4 to L_3; group 2 respondents are moderately risk seeking in that they strictly prefer L_2 over L_1 but strictly prefer L_4 to L_3; group 3 respondents are extremely risk seeking in that they strictly prefer L_2 over L_1 and weakly prefer L_3 to L_4; group 4 is an unusual group in that these respondents weakly prefer L_1 to L_2 but then weakly prefer L_3 to L_4.

Table 6 shows that both wealth and income are negatively correlated with risk-seeking behavior when we compare groups 1–3. Interestingly, group 4 respondents appear to be wealthier and have higher incomes than the other groups, which makes us think that their stated preferences may not necessarily

TABLE 6
CHARACTERISTICS OF RISK GROUPS

	Income (Rs)	Wealth (1,000 Rs)	Dryland (acres)	Irrigated Land (acres)	Children: 0–15 Years	Children: 15–25 Years: Out of School	Children: 15–25 Years: In School	Adults	Education (years)	$WTP_2 - WTP_1$ (Rs)	$WTP_3 - WTP_4$ (Rs)	Number
Risk averse (group 1)	75,323	234	2.40	3.10	.80	1.00	.20	2.60	10.00	−160.00	−160.00	5
($L_1 \geq L_2$ and $L_4 > L_3$)	(64,300)	(358)	(5.37)	(4.13)	(.84)	(1.00)	(.45)	(.89)	(1.22)	(207.36)	(108.40)	
Moderately risk seeking												
(group 2)	55,557	168	3.03	1.28	.80	.60	.34	2.37	2.43	49.56	−103.13	102
($L_2 > L_1$ and $L_4 > L_3$)	(41,594)	(217)	(2.83)	(2.04)	(.97)	(1.06)	(.62)	(.80)	(3.58)	(36.50)	(148.51)	
Extremely risk seeking												
(group 3)	41,806	79	2.48	2.57	.80	.66	.27	2.59	6.77	205.71	128.57	70
($L_2 > L_1$ and $L_3 \geq L_4$)	(41,888)	(127)	(4.34)	(5.02)	(1.04)	(1.08)	(.54)	(1.01)	(3.57)	(118.73)	(112.80)	
Risk averse/risk seeking												
(group 4)	116,525	281	2.52	5.50	.56	.96	.33	2.67	6.96	−53.70	53.70	27
($L_1 \geq L_2$ and $L_3 \geq L_4$)	(146,422)	(269)	(5.71)	(7.24)	(.80)	(.90)	(.55)	(1.11)	(4.66)	(60.32)	(35.83)	

Note. Standard errors in parentheses. Income refers to kharif income. Wealth refers to "other assets" (see note to table 5). Difference in income is statistically significantly different from zero at the 5% level between groups 2 and 3, groups 2 and 4, and groups 3 and 4. Difference in wealth is statistically significantly different from zero at the 1% level between groups 2 and 3 and groups 3 and 4 and at the 10% level between groups 2 and 4. Difference in irrigated land is statistically significantly different from zero at the 10% level between groups 3 and 4, at the 5% level between groups 2 and 3, and at the 1% level between groups 2 and 4. Difference in out-of-school 15–25-year-olds is statistically significantly different from zero at the 10% level between groups 2 and 4. Difference in education is statistically significantly different from zero at the 1% level between groups 1 and 2, groups 2 and 3, groups 1 and 3, groups 1 and 4, and groups 2 and 4.

be "mistakes" (although we have not found a satisfactory explanation for these preferences). Turning back to groups 1 and 2, we find that risk seeking is also associated with more dryland as well as more children who are currently in school (although neither of these two associations appears statistically significant when we test the differences in means across groups), which appears to fit with the qualitative evidence. As we would expect, group 3 respondents have a significantly higher valuation for L_2 relative to L_1 (i.e., $\mathrm{WTP}_2 - \mathrm{WTP}_1$) than do group 2 respondents.

We consider the difference in WTP between distributions 2 and 1 and the difference in WTP between distributions 3 and 4 as two measures of willingness to take risks.[15] Thus, a positive difference indicates a risk-loving attitude, while a negative difference indicates risk aversion. Figure 1 presents the distribution of these two variables. The mean of the first distribution ($\mathrm{WTP}_2 - \mathrm{WTP}_1$) is Rs 85, and the standard deviation is Rs 128. The mean of the second distribution ($\mathrm{WTP}_3 - \mathrm{WTP}_4$) is Rs -4, and the standard deviation is Rs 166.

In figure 2*A* we plot the predicted values of ($\mathrm{WTP}_2 - \mathrm{WTP}_1$) and ($\mathrm{WTP}_3 - \mathrm{WTP}_4$) from a regression of these variables on the total value of assets (see table C3 for the regression results), where we have assumed a quadratic specification. We see that the predicted willingness to assume risk in order to achieve high outcomes has a U-shaped relationship with wealth (as table C3 shows, these results are robust to controlling for the respondent's education). Note however in figure 2*B* and the results in table C3 that the increasing leg of the U shape appears not to be strongly present in the raw data.

In tables 7 and 8, we investigate the relationship between asset composition and the willingness to take on risk. Our basic specification is as follows:

$$y_i = \alpha + \beta_0 \mathrm{College}_i + \beta_1 \mathrm{Noncollege}_i + \gamma_0 \mathrm{TotalLand}_i + \gamma_1 \mathrm{FractionDry}_i + \delta \mathbf{X}_i + e_i,$$

where y denotes a measure of risk seeking; College denotes the number of college-age members of individual i's household; Noncollege denotes the number of non-college-age members; TotalLand denotes the total land (in acres) owned by the household; FractionDry denotes the fraction of this total land that is not irrigated; $\mathbf{X}$ denotes a vector of controls including the individual's education (in years), the value of his nonland wealth, and village fixed effects; and e denotes an unobserved error term. In this specification, our interest lies in the coefficients on College and FractionDry, which capture the potential for invest-

[15] Using the language of Just and Lybbert (2009), these are measures of marginal risk aversion.

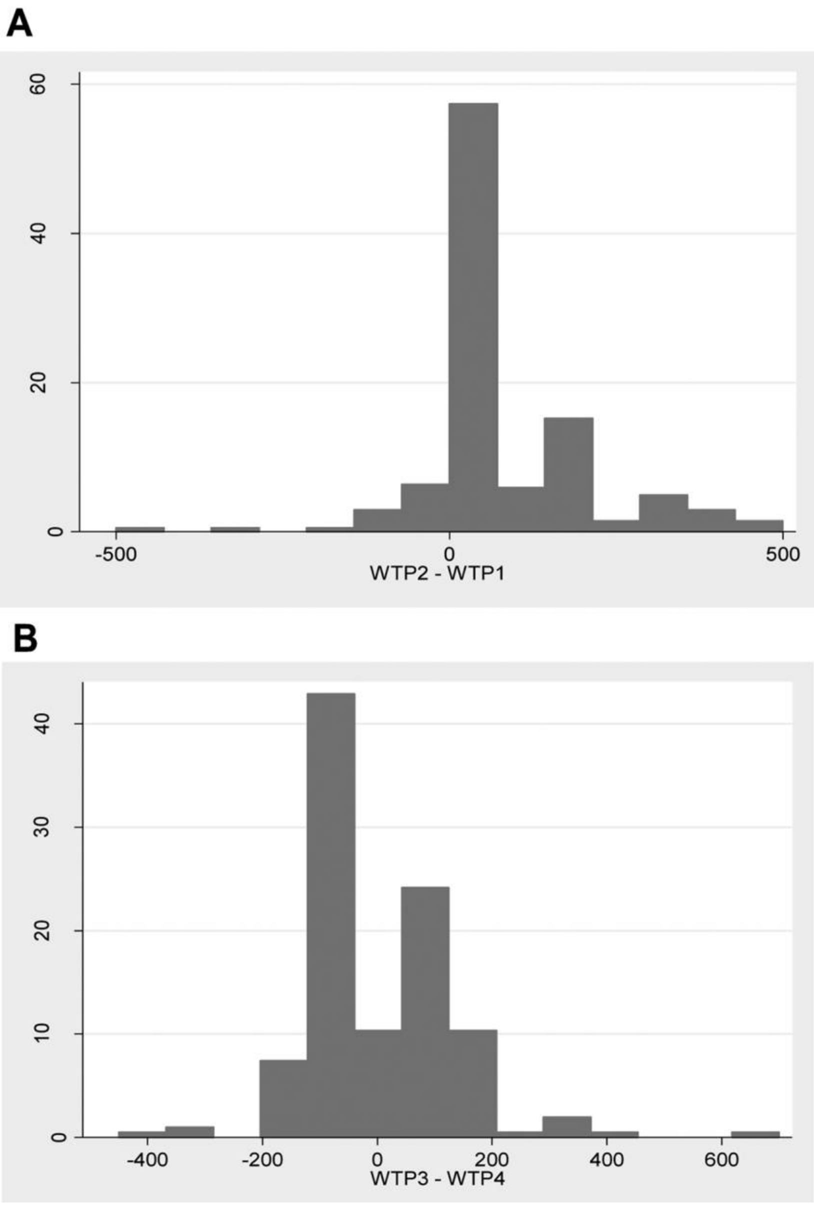

Figure 1. *A*, Histogram of $WTP^2 - WTP^1$; *B*, histogram of $WTP^3 - WTP^4$ (one observation of $-1{,}500$ was dropped to keep a similar scale as in *A*).

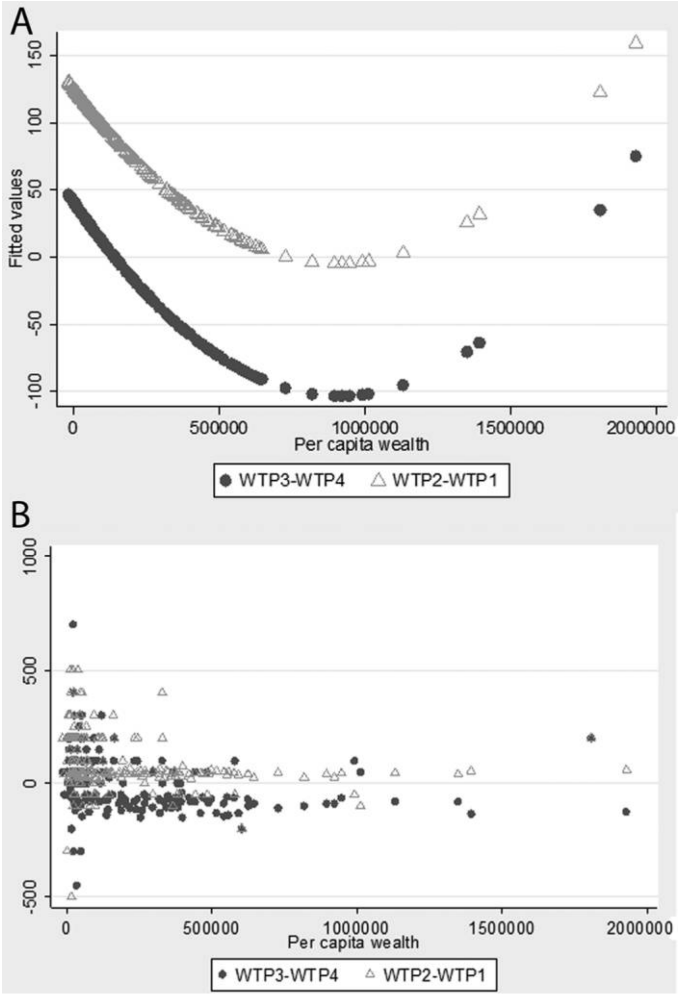

Figure 2. *A*, Predicted differences in willingness to pay (WTP) as a function of per capita wealth; *B*, differences in WTP as a function of per capita wealth (one observation of −1,500 in WTP3 − WTP4 was dropped to keep a similar scale as in fig. 1*A*). Wealth measure includes livestock, savings, borrowings and lendings, machinery, equipment, other durable goods, stocks, and land.

ment in children's college education and the potential for investment in irrigation. On the basis of our qualitative interviews, we expect that these two variables should strongly predict risk-seeking preferences.

Table 7 implements this specification using our first measure of risk seeking based on a comparison between the individual's WTP for lotteries 1 and 2. In column 1, we present the average marginal effects from a probit regression in which the dependent variable is an indicator that takes the value 1 if the in-

TABLE 7

RELATIONSHIP BETWEEN RISK LOVING AND HOUSEHOLD ASSETS: LOTTERIES 1 AND 2

	Probit	Linear Regression		Probit	Linear Regression	
	(1)	(2)	(3)	(4)	(5)	(6)
Number of college-age members	−.065	12.312**	.004	−.004	15.617***	.009**
	(.041)	(4.918)	(.005)	(.023)	(5.051)	(.004)
Number of non-college-age members	.005	.895	−.001	−.001	−1.528	−.004
	(.025)	(4.553)	(.005)	(.014)	(4.885)	(.005)
Total land (acres)	−.031**	−1.161	−.003***	−.026**	−.429	−.002**
	(.014)	(1.299)	(.001)	(.012)	(1.521)	(.001)
Fraction of land not irrigated	.209**	28.771*	.037**	.381**	22.160	.028*
	(.096)	(16.219)	(.017)	(.176)	(17.639)	(.017)
Education of decision maker (years)	.008	−.406	−.002	−.029*	−1.415	−.002
	(.012)	(1.986)	(.002)	(.017)	(1.997)	(.002)
Wealth (other assets; 1,000 Rs)	−.000	−.039	−.000	−.000	−.036	−.000
	(.000)	(.028)	(.000)	(.000)	(.038)	(.000)
Aurepalle fixed effect		14.639	.056**		−38.265*	−.023
		(18.744)	(.022)		(22.246)	(.024)
Kinkhed fixed effect	.399***	196.251***	.185***	.382*	148.747***	.112***
	(.088)	(28.701)	(.034)	(.216)	(31.918)	(.036)
Constant		56.136	−.016		52.826	−.037
		(36.122)	(.040)		(43.187)	(.047)

Note. Robust standard errors in parentheses; college-age members are those between age 15 and 25. Dependent variable in cols. 1 and 4 is an indicator that takes the value 1 if the individual preferred the second lottery to the first (with indifference being coded as a 0), and 0 otherwise. Dependent variable in cols. 2 and 5 is the difference between the individual's willingness to pay for lotteries 2 and 1; dependent variable in cols. 3 and 6 is the difference between the individual's willingness to pay for lotteries 2 and 1 divided by his willingness to pay for lottery 1; coefficients in cols. 1 and 4 denote average marginal effects. Regressions in cols. 4–6 exclude any individuals who preferred lottery 1 over 2 but also preferred lottery 3 over 4.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

dividual strictly prefers lottery 2 to lottery 1. In column 2, we present the coefficients from a linear regression in which the dependent variable is the difference in WTP between lotteries 2 and 1 (thus a positive difference denotes risk seeking). Because each individual may be evaluating the lotteries relative to a unique reference point, this might affect the amount he is willing to pay. To adjust for this reference point effect, we present in column 3 the results from a linear regression in which we scale the difference in WTP between L_2 and L_1 by the WTP for L_1. We remarked earlier that there is a (small) set of individuals who are risk averse in the comparison between L_1 and L_2 but turn out to be risk seeking in the comparison between L_3 and L_4. We think it is possible that our model may not apply to these individuals. Accordingly, columns 4–6

TABLE 8
RELATIONSHIP BETWEEN RISK LOVING AND HOUSEHOLD ASSETS: LOTTERIES 3 AND 4

	Probit	Linear Regression		Probit	Linear Regression	
	(1)	(2)	(3)	(4)	(5)	(6)
Number of college-age members	.083**	10.215**	.016***	.084*	9.653*	.013**
	(.038)	(4.742)	(.005)	(.048)	(5.362)	(.005)
Number of non-college-age members	.015	−2.394	.003	.015	−2.237	.004
	(.020)	(4.301)	(.005)	(.023)	(5.258)	(.006)
Total land (acres)	.004	−.462	.000	−.000	−.842	−.001
	(.006)	(1.041)	(.001)	(.007)	(1.359)	(.001)
Fraction of land not irrigated	−.047	8.745	−.004	.001	5.753	−.008
	(.066)	(15.222)	(.016)	(.085)	(17.619)	(.018)
Education of decision maker (years)	.001	.548	.001	.009	.907	.002
	(.009)	(1.633)	(.002)	(.013)	(1.889)	(.002)
Wealth (other assets; 1,000 Rs)	−.000	−.024	−.000	−.000	−.035	−.000
	(.000)	(.031)	(.000)	(.000)	(.037)	(.000)
Aurepalle fixed effect		−131.818***	−.195***		−118.960***	−.163***
		(15.618)	(.018)		(24.075)	(.026)
Kinkhed fixed effect	.169**	76.184***	.016	.232***	85.365***	.042
	(.071)	(22.881)	(.020)	(.079)	(29.799)	(.028)
Constant		56.136	−.016		52.826	−.037
		(36.122)	(.040)		(43.187)	(.047)

Note. Robust standard errors in parentheses; college-age members are those between age 15 and 25. Dependent variable in cols. 1 and 4 is an indicator that takes the value 1 if the individual preferred the third lottery to the fourth (with indifference being coded as a 0), and 0 otherwise. Dependent variable in cols. 2 and 5 is the difference between the individual's willingness to pay for lotteries 3 and 4; dependent variable in cols. 3 and 6 is the difference between the individual's willingness to pay for lotteries 3 and 4 divided by his willingness to pay for lottery 3; coefficients in cols. 1 and 4 denote average marginal effects. Regressions in cols. 4–6 exclude any individuals who preferred lottery 1 over 2 but also preferred lottery 3 over 4.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

redo the estimations dropping this set of individuals. Finally, table 8 repeats the estimation exercise using our second measure of risk seeking based on the comparison between lotteries L_3 and L_4.

We begin by discussing the results in table 7. Although not a significant predictor in the probit regression, the number of college-age members is significantly correlated with the difference in WTP between L_2 and L_1. In particular, having an extra college-age individual in the household increases the difference in WTP by Rs 12–15. In contrast, the effect of the number of non-college-age members on the probability of risk seeking and the difference in WTP is neither economically nor statistically significant. In all the specifications, the fraction of dryland is a significant correlate of risk seeking. A 10% increase in the fraction of dryland increases the probability of risk seeking by 2%–4% and increases the difference in WTP by about Rs 2. As expected, the total landholding, being a measure of household wealth, is (significantly) negatively correlated with risk seeking in these regressions. The household's nonland wealth appears to be negatively related to risk seeking (as per the point estimates), but the effect is not statistically significant. Also notable is that the education level of the individual does not significantly predict either his propensity for or degree of risk seeking.

Turning to the results in table 8, we find that the number of college-age members continues to be significantly correlated with risk seeking in the comparison between L_3 and L_4. Having an extra college-age individual in the household increases the probability of risk seeking by about 8% and increases the WTP between the lotteries by about Rs 10. However, differently from the results in table 7, the fraction of dryland is no longer significantly related to risk seeking in either economic or statistical terms. These results appear to indicate that the greater risk incurred by choosing L_3 over L_4 is not justified by the returns to irrigation but may be justified by the returns to higher education. This is not implausible: as we noted in Section II.A, the cost of digging a well (a common source of water for irrigation) is high, and because the success of the well is not guaranteed, irrigation may constitute a riskier investment than education. (This is leaving aside the fact that, in part, irrigation is intended as an insurance against low rainfall.) Indeed, our conversations with farmers on the field revealed that they were quite worried about the potential for wells to fail. The exact location (in terms of accessibility) of groundwater was not known to any farmer, and as a result, it was reported that wells frequently failed to reach the groundwater table, and multiple attempts had to be made. In fact, a common practice in these villages appeared to be to engage a local water diviner whose job was to predict the correct spot in which to dig a well.

A reasonable hypothesis is that the prospect for undertaking investments in irrigation (as an underlying motivation for risk taking) may be more attractive, the greater the perceived availability of groundwater. The 2001–2 ICRISAT survey asked farmers whether they had attempted to dig a well in the last 15 years and whether the well was successful. It is therefore possible, at least in principle, to use an individual's prior success as a measure of his own perception of the availability of ground water. However, this prior success rate is only defined for farmers who had attempted to dig a well, and there are very few such individuals in the 2001 data. Instead, we use the 2001 data to construct village-level estimates of the success rate of attempted wells and interact these village-level measures with the explanatory variable of interest, namely, the fraction of the farmer's land that is dry. Specifically, we include in our regression interactions between the fraction of dryland and (i) the number of attempted wells in the village in 2001 and (ii) the proportion of successful attempts in the village in 2001. We would expect that the coefficient on the interaction between dryland and the prior success rate would be positive, indicating that farmers who are more optimistic about the groundwater availability may be more willing to take risks in order to be able to afford a well. The results, reported in tables C4 and C5, are however quite imprecise, owing to the limitations of these measures of groundwater availability. Although the coefficient on the interaction is indeed positive and marginally significant in some regressions, it is negative and insignificant in others.

Overall, the results in tables 7 and 8 are consistent with the notion that the prospect of being able to undertake large investments with potentially high returns can be a justification for risk seeking. We now present a simple formalization of this idea.

IV. A Simple Model of Risk-Loving Behavior

We outline here a simple illustrative model to capture the idea that nonconvexities can induce risk taking. Imagine a credit-constrained farmer who lives for two periods and is risk neutral (i.e., his Bernoulli utility function is a linear function of wealth) and that in each period he can choose between a risky technology and a safe technology.[16] In appendix B, we show that the essential logic extends to the case in which the farmer is strictly risk averse.

If we assume that the two technologies give the same expected profit, the farmer will be indifferent between the two in both periods. However, the farmer can also invest in an asset that increases profits in the second period (e.g., this could represent an irrigation project). The farmer may then opt for the risky technology in the first period if the safe technology does not generate enough profit to cover the fixed cost needed for the irrigation project.

It is clear that the potential returns to this investment will depend on the asset position of the farmer. For instance, a farmer who owns more dryland will—under certain conditions—benefit more from installing an irrigation system, compared to a farmer who owns less dryland. Similarly, a farmer who has school-going children of an age at which they might benefit from an investment in higher education might benefit more compared to a farmer who does not have school-going children of that age group.

We purposely abstract from several aspects of the agricultural decision-making process, such as pesticide, fertilizer, and other variable-input decisions. In addition, we assume that the farmer is credit constrained (he has no access

[16] This model is inspired by the work of Carter and May (1999, 2001), Barrett and Carter (2001–2), Lybbert and Barrett (2011), and Lybbert et al. (forthcoming).

to credit), has a fixed amount of land $\bar{L} > 0$, and during the first period has no savings or irrigation system. For simplicity, we will assume that no storage is possible, so that the only way to transfer consumption from the first period to the second is to invest in the asset. It is important to note that while we discuss the decision to invest in a new irrigation system, a similar model could apply to any type of large fixed-cost investment that allows the farmer to move to a superior production function.

Assume that in each time period $t \in \{1, 2\}$, the farmer can choose between two technologies: a "safe" technology that always yields $f(\bar{L}, R)$, where R indicates whether the land is irrigated ($R \in \{0, 1\}$), and a "risky" technology that yields $f(\bar{L}, R) + \varepsilon$ with probability 1/2 and $f(\bar{L}, R) - \varepsilon$ with probability 1/2, with ε denoting the random component of the production function. Assume that $f(\bar{L}, 1) > f(\bar{L}, 0)$ (i.e., irrigation increases average land productivity) and that $f(\bar{L}, R) - \varepsilon > 0$; that is, subsistence (defined as zero consumption) is guaranteed even if one obtains the low yield. For simplicity, we assume that the production function exhibits constant returns to scale (i.e., $f(\bar{L}, \cdot) = \bar{L}f(1, \cdot)$) and that no land results in no production (i.e., $f(0, \cdot) = 0$). The former assumption implies that we can readily extend the model to the experimental setup, as we elicited WTP for a bag of seeds for 1 acre of land.[17]

The per period Bernoulli utility function is given as $u(c)$, where c denotes consumption. The utility function is assumed to be linear (i.e., $u(c) = c$). We assume that a farmer cannot opt for negative consumption. Acquiring an irrigation system requires a lump sum fixed investment $r > 0$. We assume that the cost of an irrigation system is substantial but feasible, and in particular that

$$f(\bar{L}, 0) + \varepsilon > r > f(\bar{L}, 0). \tag{5}$$

At the start of the first period, the farmer choose between the safe and the risky technologies. After the uncertainty is revealed and the proceeds are obtained, the farmer decides whether to invest in the irrigation technology and, finally, consumes. At the start of the second period, the farmer again makes a decision

[17] Note that if one assumes increasing, or more commonly decreasing, returns to scale, the WTP depends on the amount of land one has. It is not obvious whether the elicited WTP would in that case refer to the average WTP or the marginal WTP (of, e.g., the first acre of land). Intuitively, an increasing-returns-to-scale production function does not change the results of the model as the potential returns to the investment can be magnified production functions. However, additional assumptions need to be imposed for the results to continue to hold for a decreasing-returns-to-scale production function. For a discussion on returns to scale in similar contexts, see Binswanger, Deininger, and Feder (1995) and Ray (1998).

between the safe and the risky technology, after which the uncertainty is revealed, proceeds are collected, and he consumes.

Let us approach this two-period problem using backward induction, starting from the second period. From the setup, it is clear that in the second period the farmer will be indifferent between the risky and the safe technologies.

Now note that if the farmer chooses the safe technology in the first period, following (5) he will be unable to invest in an irrigation system. However, if the farmer chooses the risky technology in the first period and obtains the high yield, he has the option to invest in an irrigation system. In that case, he will compare the outcome with irrigation to the outcome without irrigation:

$$\begin{aligned} \text{without irrigation:} \quad & [f(\bar{L},0)+\varepsilon]+\delta f(\bar{L},0), \\ \text{with irrigation:} \quad & [f(\bar{L},0)+\varepsilon-r]+\delta f(\bar{L},1), \end{aligned} \tag{6}$$

where $\delta \in (0,1)$ is the discount factor, summarizing preferences over time. The farmer opts for the irrigation system if and only if

$$\delta[f(\bar{L},1)-f(\bar{L},0)]>r. \tag{7}$$

Under conditions (5) and (7),[18] the difference in WTP between the risky and the safe technology is

$$\begin{aligned} \mathrm{WTP}_{\mathrm{risky}}-\mathrm{WTP}_{\mathrm{safe}} &= \frac{1}{2}[f(\bar{L},0)-\varepsilon+\delta f(\bar{L},0)] \\ &+ \frac{1}{2}[f(\bar{L},0)+\varepsilon-r+\delta f(\bar{L},1)]-[f(\bar{L},0)+\delta f(\bar{L},0)]. \end{aligned} \tag{8}$$

Rewriting (8):

$$\mathrm{WTP}_{\mathrm{risky}}-\mathrm{WTP}_{\mathrm{safe}}=\frac{1}{2}[\delta f(\bar{L},1)-\delta f(\bar{L},0)-r]. \tag{9}$$

Following (7), $(\mathrm{WTP}_{\mathrm{risky}}-\mathrm{WTP}_{\mathrm{safe}})$ is strictly positive. Note now that whether (5) and (7) are satisfied depends (among other factors) on $\bar{L}$. Assuming that these conditions continue to hold, one could take the derivative (9) with respect to land, obtaining

[18] Equations (5) and (7) imply that the returns to investment are very large compared to the base return. This condition might be difficult to meet in a two-period model but could be easily met if one imagines the increased return to be sustained over a longer period of time.

$$\frac{1}{2}\delta\left[\frac{\partial f(\bar{L},1)}{\partial L}-\frac{\partial f(\bar{L},0)}{\partial L}\right]. \tag{10}$$

Assuming constant returns to scale, expression (10) is strictly positive. Thus, the difference in WTP increases as one has more dryland. Moreover, this increase in WTP is increasing in the returns to irrigation.

V. Concluding Discussion

In this article we have analyzed the relationship between attitudes toward risk and investment possibilities. We are able to take advantage of a unique data set that we collected among farmers in India's semiarid tropics, which contains information on farmers' assets and the results from a risk experiment. This risk experiment consisted of four hypothetical farming seasons. For each season, the farmer was asked how much he would be willing to pay for a bag of cotton seed resulting in a particular yield distribution.

Comparing the WTP for the various yield distributions, we find a high incidence of risk-seeking behavior. Further, we find a robust relationship between risk-loving behavior and wealth and assets (which remains even after controlling for the respondent's education). In particular, the potential for investment in irrigation and children's college education appear to be strongly correlated with risk-seeking behavior.

The setup of our experiment is distinct from previous studies in a number of significant ways. In particular, our experiments (i) involved hypothetical payoffs, (ii) were explicitly framed in an agricultural context, and (iii) involved high stakes. Regarding i, while it is possible that subjects respond differently to hypothetical versus real gambles, the evidence from the experimental literature is mixed. Differently from laboratory experiments, we explicitly framed our lotteries in terms of yield from an agricultural crop (cotton). This served to add realism to the experiment, which partly compensated for the hypothetical nature of the payoffs. Providing a familiar context made it easy for the farmers to understand the gambles and what they represented.

Finally, whereas prior studies have typically presented respondents with small- and medium-stakes gambles, our experiments involved fairly large payoffs on the order of an individual's annual income. We think, on the basis of our qualitative interviews as well as our analysis of the data, that this factor may account for our finding of risk-loving preferences. We also think that our results, while different, are not necessarily incompatible with the findings of prior studies. The logic that high-fixed-cost investments with high returns can justify risk loving in the face of high-payoff gambles would also imply that if the payoffs are not large enough then these investments may be out of the question, in which case we would find ourselves back in the world of risk aversion.

The idea of the "gambling poor" is certainly not novel—Friedman and Savage (1948) argue that the curvature of the utility function of the "poor" is different from the rich, resulting in risk-taking behavior. Banerjee and Newman (1994) argue that poverty traps might result in "risk-loving poor" but that credit constraints might restrict their set of options. Empirically, the "gambling poor" have been noted in other contexts. Mo (2011) finds that perceived relative poverty induces more risk-seeking behavior with regard to migration and economic opportunities in Nepal. Clotfelter (1979), Borg and Mason (1988), and Hansen, Miyazaki, and Sprott (2000) find that the poor in the United States spend a greater percentage of their income on lotteries and gambling than others.

Binswanger's (1980) study of risk preferences in the same ICRISAT villages provides an interesting point of comparison with our study. Binswanger's experiments were done with three stake levels: low, medium, and high. His high stakes are comparable to our stakes (on the order of annual income) and were also hypothetical, whereas the low- and medium-stakes experiments involved real payoffs. He found high levels of risk aversion: for the hypothetical stakes, he finds that 14% are severely risk averse, 52% intermediately, and 28% moderately, compared with the medium real stakes where he finds that 5% are severely risk averse, 35% intermediately, 40% moderately, and 5% are neutral (the intermediate range is classified as a Partial Relative Risk Aversion between 1.74 and 0.812).

The fact that Binswanger's respondents were risk averse even when confronted with hypothetical payoffs is in a sense comforting. But this makes our results even more striking, given that we explicitly provided a realistic context for our gambles, and we are therefore even more confident that our respondents understood the game (and were thus even less likely to mistakenly prefer risky distributions to safe ones).

We offer two speculative hypotheses to explain the differences between our results and Binswanger's. First, while credit markets in developing countries have always been incomplete, a number of factors such as climate change, the availability of genetically modified seeds, and new agricultural output and labor market opportunities have changed the cost-benefit calculations of investments in irrigation and education in India in the last few decades. In particular, technological improvements have lowered the cost of groundwater irrigation in India and led to a boom in borewell construction. According to statistics from the Indian Water Management Institute, the number of wells in India has increased from about 1 million in 1960 to nearly 19 million in 2000. Shah (2005) shows that while groundwater extraction has been growing in many countries, India is an extreme outlier, with more than 200 cubic kilometers of water extracted in 2000 (compared to, e.g., about 75 cubic kilometers in the case of China). At the same time, the cost of borewell construction is not insignificant, and fragmented landholdings mean that many plots of land lie unirrigated (Shah 1993).

Second, our gambles were presented as yield distributions corresponding to a cash crop, cotton. There is evidence from other settings that risk preferences may be sensitive to the context (Wolf and Pohlman 1983; Barseghyan, Prince, and Teitlebaum 2011; Einav et al. 2012). Thus, we think it is possible that farmers are more ready to take risks in the context of cash crops but are more likely to be risk averse when it comes to food crops. This may constitute an interesting avenue for future research.

To conclude, we investigate risk-seeking behavior among cotton farmers in India and find that nonconvexities associated with certain investments might play an important role. The presence of these nonconvexities has implications for the design of a poverty alleviation program, as the impact of credit or cash transfers programs can be expected to depend, in a nonlinear manner, on the household's asset status (see also Barrett and Carter [2013] on the implications of poverty traps for policy).

Appendix A

The experiment was conducted among all households who have made farming decisions in the past 7 years or intend to make farming decisions in the future. The reason for this selection is the experiment's context-specific nature, which would make little sense to nonagricultural households (as we found out during the trial round). To obtain responses based on recent experiences, we decided to interview only the households who farmed within the past 7 years, since in that time frame many new technologies were introduced, such as genetically modified cotton seeds. The households that did not satisfy these criteria did not participate in the experiment.

The experiment took place at the end of a 3–5 hour interview, interrupted with a few tea breaks. The respondent, who was the main decision maker with regard to agriculture, received about US$1.5 for participating in the interview, the equivalent of about 1 day's labor. In addition, the respondents in each village were invited every 2–3 years to participate in a day trip funded by this study together with other studies. The interview took place in the respondent's residence. No active effort was undertaken to separate the respondent from other family members, but as the interview took several hours, only in a few cases were family members present throughout the interview. For the more subjective questions (such as in this experiment), the respondent was not allowed to discuss the answers with his family members.

The respondent was given ample time to learn the game. As the game was preceded by another game involving visual representations of a distribution function, the respondents were comfortable with the Fisher-Price blocks of various colors. The instructions for the enumerators are given below. The first author taught the enumerators this game, both in a lab setting and subsequently in a field setting, so we are confident that all enumerators understood the game and conducted it in the same manner. For each distribution, the farmer was asked to imagine going to the store and buying seeds for this season.

Instructions for the Enumerators

The goal of this part of the questionnaire is to get an idea of the risk aversion of the respondents. This question is asked of all households who have made farming decisions in the past 7 years and/or intend to make farming decisions in the future. We will use Fisher Price building blocks to represent yield distributions of cotton, and ask the respondent how much they would be willing to pay for a bag of these seeds (sufficient for 1 acre of land). Tell the respondent that we will play another game with him/her. You say: "Just like on your own farm, you will have the chance to buy seeds at the beginning of each season, but not know the yield until the end of the season. On your own farm, how much you earn depends on whether it is a good year or a bad year. In this game it is the same. In a good year, you will harvest more, in a bad year you will harvest less."

Then, place the building blocks on the white board. One block represents 5%, requiring a total of 20 blocks for the game.

- The green blocks = high yield (8 quintal/acre) good season
- The yellow blocks = average yield (6 quintal/acre) average season
- The red blocks = low yield (4 quintal/acre) bad season

Explain to the respondent the meaning of the different blocks. Do several exercises holding up one block, two blocks etc. to check whether he can associate the percentages with the blocks. Once the respondent understands the meaning of the blocks, make 2 trial distributions to learn the game. Then proceed with the 4 distributions given in the questionnaire. For each distribution ask how much the respondent is willing to pay at most, starting from 100 Rs and working your way up in steps of 50 Rs until the farmer changes his answer.

Then, decrease the amount to identify the exact point (to the nearest 5 Rs). After the respondent has answered, verify and write down the answers (in Rs) in the boxes.

- Trial experiment 1 [100% in low yield]
- Trial experiment 2 [50% in low yield and 50% in average yield]
- Experiment 1 [25% in low yield, 50% in average yield and 25% in high yield]
- Experiment 2 [30% in low yield, 40% in average yield and 30% in high yield]
- Experiment 3 [30% in low yield, 30% in average yield and 40% in high yield]
- Experiment 4 [10% in low yield, 55% in average yield and 35% in high yield]

Appendix B

We now lay out the farmer's decision problem when $u''(c) < 0$. As before, let us approach this two-period problem using backward induction, starting from the second period. In the second period, after the farmer has made his irrigation investment decision, he compares the expected utility of the safe and risky technologies. As his Bernoulli utility function is (strictly) concave, he opts for the safe technology. Again, if the farmer chooses the safe technology in the first period, following (5), he is unable to invest in an irrigation system. However, if he chooses the risky technology in the first period and obtains the high yield, he has the option to invest in an irrigation system. In that case, he will compare the outcomes with and without irrigation:

$$\begin{aligned} \text{without irrigation:} \quad & u[f(\bar{L}, 0) + \varepsilon] + \delta u f(\bar{L}, 0), \\ \text{with irrigation:} \quad & u[f(\bar{L}, 0) + \varepsilon - r] + \delta u f(\bar{L}, 1), \end{aligned} \tag{B1}$$

where $\delta \in (0, 1)$ is the discount factor, summarizing preferences over time. In this case, the farmer opts for the irrigation system if and only if

$$u[f(\bar{L}, 0) + \varepsilon - r] + \delta u[f(\bar{L}, 1)] > u[f(\bar{L}, 0) + \varepsilon] + \delta u[f(\bar{L}, 0)]. \tag{B2}$$

Under conditions (5) and (B2), the difference in WTP between the risky and the safe technology in the first period is[19]

[19] Note here that we simplified the farmer's decision-making problem by equating the WTP to the discounted expected value, thereby ignoring the initial wealth. This simplification does not change the main result.

$$\begin{aligned}\mathrm{WTP}_{\mathrm{risky}} - \mathrm{WTP}_{\mathrm{safe}} = {} & \frac{1}{2}[u[f(\bar{L},0) - \varepsilon] + \delta u[f(\bar{L},0)]] \\ & + \frac{1}{2}[u[f(\bar{L},0) + \varepsilon - r] + \delta u[f(\bar{L},1)]] \\ & - [u[f(\bar{L},0)] + \delta u[f(\bar{L},0)]].\end{aligned} \tag{B3}$$

The sign of (B3) is ambiguous and depends on further assumptions on the returns to the investment. However, assuming constant returns to scale, the derivative of (B3) with respect to land is strictly positive.

Appendix C

TABLE C1
TESTING FOR ORDER EFFECTS

	(1)
Distribution 2	84.3*** (12.6)
Distribution 3	220.1*** (12.6)
Distribution 4	224.4*** (12.6)
Constant	705.5*** (8.9)

Note. Dependent variable is willingness to pay. Standard errors in parentheses. Regression includes individual fixed effects. The difference between the second and the third distributions is statistically significant at the 1% level. The difference between the third and the fourth distributions is not statistically significant.
*** $p < .01$.

TABLE C2
CORRELATES OF INDIVIDUAL LEVEL OUTPUT PRICE AND INPUT COSTS: ORDINARY LEAST SQUARES REGRESSION

	Output Price (Rs/Quintal)	Input Cost (Rs/Acre)
Number of members	−11.3	216.8
	(17.3)	(155.8)
Number of adult members	20.3	−230.3
	(22.3)	(199.8)
Dryland (acres)	2.7	−5.7
	(5.1)	(45)
Irrigated land (acres)	3.4	40.6
	(5.2)	(40.9)
Access to a plot of good soil quality	50.8	1,044.9
	(81.2)	(712.5)
Number of plots of good soil quality > 1 acre	14	−24.1
	(20.6)	(182.7)
Education level of decision maker (years)	9.6	−2.7
	(5.9)	(53.7)

TABLE C2 (*Continued*)

	Output Price (Rs/Quintal)	Input Cost (Rs/Acre)
Aurepalle fixed effect	−211.2***	3,763.8***
	(57.8)	(522.6)
Kinkhed fixed effect	−39.8	−799.3
	(58.2)	(508.2)
Constant	2,037.1***	3,133.6***
	(95.1)	(836.7)

Note. Standard errors in parentheses.
*** $p < .01$.

TABLE C3
RELATIONSHIP BETWEEN RISK LOVING AND WEALTH: ORDINARY LEAST SQUARES REGRESSION

	$WTP_2 - WTP_1$ (1)	$WTP_3 - WTP_4$ (2)	$WTP_2 - WTP_1$ (3)	$WTP_3 - WTP_4$ (4)
Per capita wealth (10,000 Rs)	−2.83***	−3.53***	−2.78***	−3.25***
	(.65)	(.64)	(.66)	(.62)
Per capita wealth^2	.02***	.02***	.02***	.02***
	(.00)	(.00)	(.00)	(.00)
Education level of decision maker (years)			1.53	7.75***
Constant	124.05***	54.52***	116.20***	14.74
	(12.46)	(12.26)	(16.13)	(15.27)

Note. Standard errors in parentheses; $N = 203$. Dependent variable is willingness to pay (WTP) for the second (third) distribution minus the WTP for the first (fourth) distribution in the first and third (second and fourth) columns. Wealth includes livestock, land, savings, borrowings and lendings, machinery, equipment, other durable goods, and stocks.
*** $p < .01$.

TABLE C4
RELATIONSHIP BETWEEN RISK LOVING AND HOUSEHOLD ASSETS: LOTTERIES 1 AND 2

	(1)	(2)	(3)	(4)	(5)	(6)
Number of college-age members	.026**	10.685**	.015***	.021*	10.226*	.013**
	(.012)	(4.874)	(.005)	(.012)	(5.493)	(.005)
Number of non-college-age members	.003	−2.004	.002	.012	−1.226	.005
	(.014)	(4.374)	(.005)	(.018)	(5.608)	(.006)
Total land (acres)	.058	9.651	.020	−.065	−37.259	−.014
	(.054)	(17.208)	(.018)	(.325)	(81.337)	(.088)
Fraction of land not irrigated	−3.358**	−315.556	−.627*	−3.902*	−323.422	−.861
	(1.348)	(336.724)	(.375)	(2.296)	(567.459)	(.592)
Fraction of land not irrigated × success rate of wells	6.743**	703.349	1.300*	7.796*	715.385	1.744
	(2.629)	(683.242)	(.741)	(4.408)	(1,104.483)	(1.141)
Fraction of land not irrigated × number of well attempts	−.021***	−2.648	−.004*	−.024*	−2.683	−.006*
	(.008)	(2.236)	(.002)	(.013)	(3.300)	(.003)

TABLE C4 (*Continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
Education of decision maker (years)	−.001	.546	.001	−.000	.955	.002
	(.005)	(1.730)	(.002)	(.006)	(2.041)	(.002)
Wealth (other assets; 1,000 Rs)	−.000	−.031	−.000	−.000	−.035	−.000
	(.000)	(.030)	(.000)	(.000)	(.030)	(.000)
Aurepalle fixed effect	−.869***	−122.252***	−.199***	−.810***	−129.558***	−.194***
	(.054)	(18.384)	(.023)	(.114)	(36.068)	(.041)
Kinkhed fixed effect	−.024	53.579	−.012	.016	44.086	−.012
	(.094)	(36.200)	(.034)	(.144)	(48.920)	(.049)
Constant	.818***	60.878*	.004	.763***	71.489	.002
	(.095)	(33.891)	(.042)	(.139)	(46.115)	(.054)

Note. Robust standard errors in parentheses; college-age members are those between age 15 and 25. Dependent variable in cols. 1 and 4 is an indicator that takes the value 1 if the individual preferred the second lottery to the first (with indifference being coded as a 0), and 0 otherwise; coefficients in cols. 1 and 4 are from linear regressions (the corresponding probit regressions could not be estimated with the inclusion of the interaction variables). Dependent variable in cols. 2 and 5 is the difference between the individual's willingness to pay for lotteries 2 and 1; dependent variable in cols. 3 and 6 is the difference between the individual's willingness to pay for lotteries 2 and 1 divided by his willingness to pay for lottery 1. Regressions in cols. 4–6 exclude any individuals who preferred lottery 1 over 2 but also preferred lottery 3 over 4. "Number of well attempts" and "success rate of wells" are village-specific averages computed from 2001 ICRISAT survey data.

* $p < .1$.

** $p < .05$.

*** $p < .01$.

TABLE C5

RELATIONSHIP BETWEEN RISK LOVING AND HOUSEHOLD ASSETS: LOTTERIES 3 AND 4

	(1)	(2)	(3)	(4)	(5)	(6)
Number of college-age members	−.025	13.364**	.005	.000	16.782***	.010**
	(.015)	(5.139)	(.005)	(.008)	(5.207)	(.005)
Number of non-college-age members	.005	.751	−.002	−.003	−1.686	−.006
	(.014)	(4.481)	(.005)	(.008)	(5.442)	(.006)
Total land (acres)	−.205***	−22.540	−.043*	−.308	−60.696	−.091
	(.060)	(18.417)	(.022)	(.243)	(99.134)	(.105)
Fraction of land not irrigated	2.295	348.537	.645	1.496	497.991	.812
	(1.460)	(382.039)	(.451)	(1.047)	(494.237)	(.536)
Fraction of land not irrigated × success rate of wells	−4.246	−554.451	−1.153	−2.759	−845.574	−1.476
	(2.809)	(769.468)	(.881)	(2.018)	(977.215)	(1.040)
Fraction of land not irrigated × number of well attempts	.011	.854	.003	.007	1.706	.004
	(.008)	(2.475)	(.003)	(.006)	(3.012)	(.003)
Education of decision maker (years)	.002	.212	−.001	−.004	−.658	−.001

TABLE C5 (*Continued*)

	(1)	(2)	(3)	(4)	(5)	(6)
	(.006)	(2.031)	(.002)	(.003)	(1.982)	(.002)
Wealth (other assets; 1,000 Rs)	−.000*	−.042	−.000	−.000	−.042	−.000
	(.000)	(.027)	(.000)	(.000)	(.030)	(.000)
Aurepalle fixed effect	.476***	36.259	.067**	.043	−20.124	−.015
	(.097)	(27.359)	(.032)	(.087)	(46.184)	(.055)
Kinkhed fixed effect	.411***	185.147***	.187***	.018	134.522**	.111
	(.100)	(39.717)	(.044)	(.105)	(58.165)	(.067)
Constant	.607***	30.190	.090*	.990***	85.985*	.164***
	(.095)	(33.891)	(.042)	(.139)	(46.115)	(.054)

Note. Robust standard errors in parentheses; college-age members are those between age 15 and 25. Dependent variable in cols. 1 and 4 is an indicator that takes the value 1 if the individual preferred the third lottery to the fourth (with indifference being coded as a 0), and 0 otherwise; coefficients in cols. 1 and 4 are from linear regressions (the corresponding probit regressions could not be estimated with the inclusion of the interaction variables). Dependent variable in cols. 2 and 5 is the difference between the individual's willingness to pay for lotteries 3 and 4; dependent variable in cols. 3 and 6 is the difference between the individual's willingness to pay for lotteries 3 and 4 divided by his willingness to pay for lottery 3. Regressions in cols. 4–6 exclude any individuals who preferred lottery 1 over 2 but also preferred lottery 3 over 4. "Number of well attempts" and "success rate of wells" are village-specific averages computed from 2001 ICRISAT survey data.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

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